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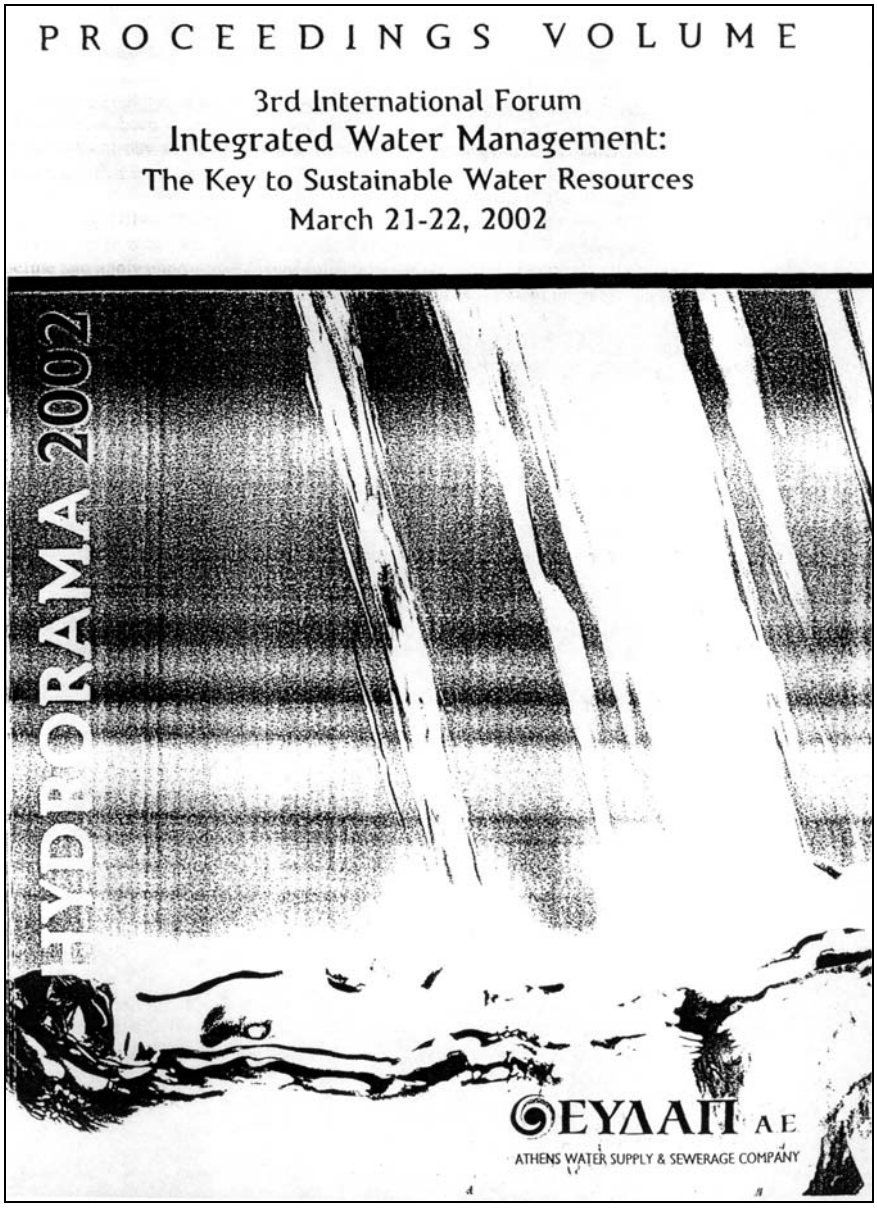

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A MULTI-PARAMETRIC APPROACH OF WATER MANAGEMENT IN THE FRAME OF SUSTAINABLE DEVELOPMENT

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ABSTRACT

The term **"water shortage"** is referring to the inability to cover quantitative and qualitative water needs for a specific time period, in a specific area and it is caused by a number of factors. During the past 50 years, the Hellenic state has repeatedly dealt with the issue of water shortage, but it seems that the measures have been of temporary and fragmented character. The European Union, taking into account the present day scientific results, considers the management of water resources as a multi-parametric issue that must be confronted within the frame of sustainable development. Therefore, for the confrontation of the problem in this framework, the knowledge of the characteristics of the basic geographical units (**R**iver **B**asin **D**istricts) is necessary. Management and operation of the appropriate authorities will take place within these units in order to accumulate and process all knowledge and hence define and apply appropriate management models. A model of central and regional management of water resources is suggested, based on a range of actions that ensure the multi-parametric approach of the problem in each R.B.D. individually.

1. WATER SHORTAGE

The term **"water shortage"** is referring to the inability to cover quantitative and qualitative water needs for a specific time period, in a specific area. Water shortage is caused by different factors, the most important being the demographic explosion, the rise of the living standards, climatic changes and improper management.

Demographic explosion is not an immediate danger for Greece at this time. Nevertheless, urban pull causes unequal distribution of population and, consequently, of water demands. This fact is combined with increasing attraction of emigrants towards the EU and, moreover, towards Greece.

In addition, there are climatic changes, due to several causes, some of which are astronomic phenomena. Many of these changes are periodical, and they are repeated within decades, hundreds or many thousands of years. This fact reflects on the global temperature and precipitation in the same periodical way. Nevertheless, periods of drought recorded in historical times (8^{th} century B.C., 2^{nd} century A.C., 12^{th} century A.C.) have never turned the north circum-Mediterranean areas into desert. Of course, these droughts have largely influenced the –mainly agricultural- economy of the time, but never interrupted it. In any case, scientific knowledge and know-how of those times cannot be compared with toady's situation, but the needs are also greatly different.

Time is a factor that seems to be rather **underestimated** by groups seeking solutions to the problem of water shortage. The Master Plan about Water Resources in Greece by the Hellenic Ministry of Development, the National Technical University of Athens and the Institute of Geological and Mineral Exploration, contains, among others, estimations for Thessaly. In the diagram of Figure 1, the following conclusions are well evident; firstly, on an annual basis, the available water quantities are double than the needs. Secondly, in July, the needs are double than the available quantities, situation that is well described as water shortage. This fact indicates that the real problem about water shortage, at least in this case, is not the available quantities, but the time of availability. For example, the mid-term scenario indicates, that even with the inflow of the waters of Acheloos river, the available quantities will not be able to cover the needs, unless the latter stay at the levels of 1996.

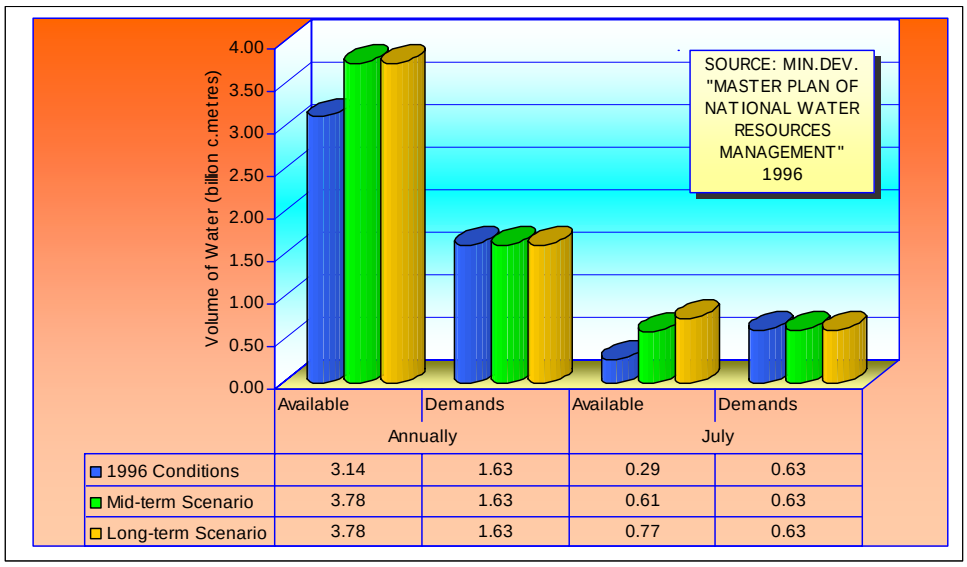

Figure 1: Demands and available water resources of Thessaly (1996 Data, Mid-term and Long-term scenario)

A second fact that has to be pointed out is that it is not possible to successfully apply the same solution to all hydrological-hydrogeological systems, even in neighbouring areas, such as the Greek basins. In Figure 2, where the mean drainage of different Greek river basins is shown, it is obvious that in basins of high drainage (and consequently with high coverage of impermeable formations) dams and ponds are probably the best solution, while in basins of low drainage (high coverage of micropermeable or karstic formations) methods of aquifer storage and recovery will be more effective in enhancing water resources.

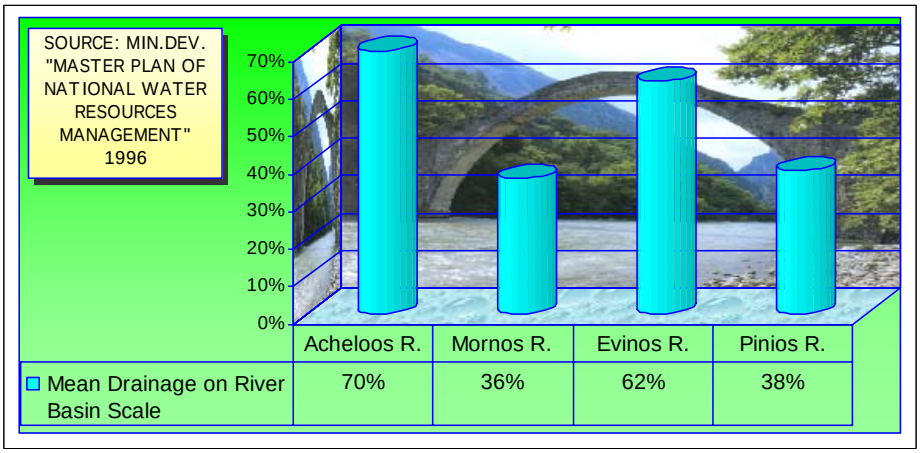

Figure 2: Mean drainage in a hydrological basin shows the percentage of precipitation that escapes to the sea. The large differences among basins reflect roughly the differences in the outcrops of geological formations of each basin.

2. THE GREEK EXPERIENCE

During the last 50 years, the Hellenic State has repeatedly dealt with water management problems, especially in periods of imminent crisis of shortage, concerning mainly large urban areas, such as Athens, as well as large agricultural zones such as Thessaly plains, the Argolic plain etc. At the same time, numerous efforts of local authorities, oganisations, companies etc have been done throughout Greece.

Nevertheless, the problem seems to come back more dramatically from time to time, and it seems that the measures taken so far have failed to confront the matter in a radical and efficient way. The cases that phenomena of antagonism between neighbouring municipalities or prefectures have raised are not few. This shows that hitherto approaches have moved towards a dead-end. The common features of almost all the efforts that have taken place in Greece till today, can be summarized as below:

1. All actions are always hasty, usually under conditions of tremendous social and financial pressure, alternating with long periods of inactivity, and loss of valuable time.
2. Studies keep within small geographical areas, limited by administrative boundaries not defined by hydrogeological criteria, thus resulting to inadequate conclusions.
3. Short-term solutions of local interest are applied, soon proving to be unsustainable, and unable to deal with the evolution of a dynamic situation.
4. The cost is disproportional, and often intolerable, mainly for farmers, in relation to the effectiveness of the solutions.
5. The absence of overall planning leads to great dispersion and loss of financial resources without the expected results. Instead, non-reversible consequences are often generated, either by means of exhaustion of the available water resources, or by means of alteration of the quality of the aquifers (salinization, ground compaction, pollution etc).
6. The method of aquifer storage and recovery in karstic or granular aquifers with flood waters has not been applied as it should, once it could show impressive results in Greece. Carbonates, such as limestone, dolomite and marble, that usually host karst formations, cover more than 30% of the Hellenic area whereas impermeable rocks, such as flysch and schists, cover nearly 40%. Neotectonic sediments (clastics, such as pelite, marl, sandstone and conglomerates), cover a total of 30% of the area, half (15%) being of neogene age and the other half being of quaternary age. Most of the neotectonic sediments have been deposited on the plains (neotectonic basins), whereas most of the alpine sediments occur on the surrounding margins and in mountainous areas, as well as on the basement of certain basins. A karstified basement can be used for artificial recharge of the overlying micro-permeable clastic sediments. If the alpine basement of the basins is taken into account, then the percentage of karstified carbonates suitable for artificial recharge is significantly greater than 30%.
7. The whole planning for the confrontation of water shortage in Greece is based on the construction of minor or major tanks and dams, which in our opinion should be constructed only in the lack of other alternatives, because:
    - Evaporotranspiration in the Hellenic area ranges around 2 metres per year.
    - Natural recharge of the downhill aquifers is interrupted. Additionally, in the plains, flood prevention works reduce natural infiltration even more, and the consequences are severe, as much as compaction, extreme lowering of groundwater surface and finally disusing of the pumping equipment.
    - A large network of pipelines should be constructed, even before the depreciation of the pumping equipment.

3. THE EUROPEAN UNION POLICY FOR WATER MANAGEMENT AND THE GREEK EFFORT

Rational water management should take into account all sides of the problem;

- A multi-parametric approach is necessary, based on the following axes:
    - Separation of the Hellenic area into large hydrogeological units (River Basin Districts, R.B.D.) as defined by the European Union (Directive Of The European Parliament And Of The Council 2000/60/EC, Establishing A Framework For Community Action In The Field Of Water Policy):

- **"River Basin District** means the area of land and sea, made up of one or more neighbouring river basins together with their associated groundwaters and coastal waters, which is identified under Article 3(1) as the main unit for management of river basins".
- The record of water demands (and their quality and quantity characteristics) by R.B.D., on a yearly basis and by time and space distribution.

- This separation should be done with the use of hydrological (surface waters) and hydrogeological (groundwaters) criteria.

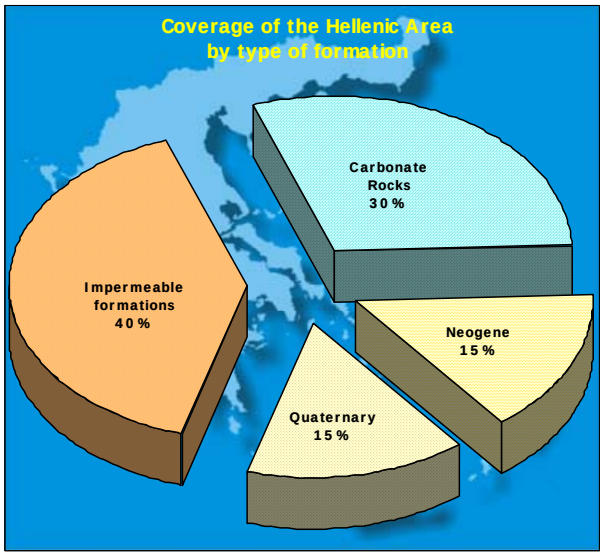

Figure 3: Coverage of the Hellenic area by type of geological formation

The European Union also focuses its policy on the above mentioned context, according to which: "The objective of achieving good water status should be pursued for each river basin, so that measures in respect of **surface water and groundwaters** belonging to the same ecological, hydrological and hydrogeological system are coordinated." (Directive 2000/60/EC (33)). "For the purposes of environmental protection there is a need for a greater integration of qualitative and quantitative aspects of both surface waters and groundwaters, taking into account the natural flow conditions of water **within the hydrological cycle**" (Directive 2000/60/EC (34)).

Water resources for every R.B.D. and their relation to the climatic changes should be estimated and evaluated.

There cannot be usage of water resources without severe environmental impact, except for the percentage of drainage and infiltrated quantities that is renewed by precipitation on a yearly basis.

Moreover, according to the Directive 2000/60/EC

- "Member States shall protect, enhance and restore all bodies of surface water, subject to the application of subparagraph (iii) for artificial and heavily modified bodies of water, with the aim of **achieving good surface water status at the latest 15 years after the date of entry** into force of this Directive" (Article 4, §1.(ii)).
- "Each Member State shall ensure that for each River Basin District or for the portion of an international River Basin District falling within its territory:
  - an analysis of its characteristics,
  - a review of the impact of human activity on the status of surface waters and on groundwater, and
  - an economic analysis of water use

- is undertaken according to the technical specifications set out in Annexes II and III and that it is completed at the latest four years after the date of entry into force of this Directive" (Article 5, §1).

Hydrogeological features, such as the geometry of the aquifer, are a condition for the understanding of the quality and quantity interaction between surface and groundwater and the estimation groundwater volume.

The combination of flood prevention and simultaneous artificial recharge is necessary, wherever applicable since the framework for the protection of water should, among others, "…contribute to mitigating the effects of floods and droughts" (Directive 2000/60/EC, Article 1, (e)). Many areas within the Hellenic territory are suitable for this combination (i.e. Thriassio plain, Thessaly, etc).

Recruitment of a wide variety of specialised scientists is fundamental for the management of a natural resource. The deep knowledge of the relevant national and European legislation is equally important as well as the application of the modern principles ruling environmental and water management.

In order to implement the above, the Hellenic State should activate a national organization of water resources management, and district units, respective to each R.B.D.:

- «Member States shall ensure the appropriate administrative arrangements, including the identification of the appropriate competent authority, for the application of the rules of this Directive within each River Basin District lying within their territory.» (Directive 2000/60/EC, Article 3, §2,6)
- "Decisions should be taken **as close as possible** to the locations where water is affected or used"(Directive 2000/60/EC, (13)).

These authorities should employ specialized scientific and technical personnel, and be equipped with state of the art technology. At the same time, all existing infrastructure and human resources already attached to other authorities involved in water management issues should be integrated under the guidance of the R.B.D. management units. Thus, the characteristics of each River Basin District will be established, and their mi-long-term potential will be evaluated, so that the appropriate measures and actions are taken.

It is clearly stated that all the above are reviewed and re-evaluated every six years and they are monitored on a systematic and comparable basis throughout the E.U.(Directive 2000/60/EC, (35), and Article 8):

- Within a river basin where use of water may have transboundary effects, the requirements for the achievement of the environmental objectives established under this Directive, and in particular all programmes of measures, should be coordinated for the whole of the River Basin District. For river basins extending beyond the boundaries of the Community, Member States should endeavour to ensure the appropriate coordination with the relevant non-member States. This Directive is to contribute to the implementation of Community obligations under international conventions on water protection and management, notably the United Nations Convention on the protection and use of transboundary water courses and international lakes, approved by Council Decision 95/308/EC1 and any succeeding agreements on its application. (Directive 2000/60/EC, (35)).
- 1. Member States shall ensure the establishment of programmes for the monitoring of water status in order to establish a coherent and comprehensive overview of water status within each River Basin District:
    - for surface waters such programmes shall cover:
        - (i) the volume and level or rate of flow to the extent relevant for ecological and chemical status and ecological potential; and
        - (ii) the ecological and chemical status and ecological potential;

- for groundwaters such programmes shall cover monitoring of the chemical and quantitative status;
- for protected areas the above programmes shall be supplemented by those specifications contained in Community legislation under which the individual protected areas have been established. (Directive 2000/60/EC, Article 8)

- 2. These programmes shall be operational at the latest six years after the date of entry into force of this Directive unless otherwise specified in the legislation concerned. Such monitoring shall be in accordance with the requirements of Annex V. (Directive 2000/60/EC, Article 8).
- Technical specifications and standardised methods for analysis and monitoring of water status shall be laid down in accordance with the procedure laid down in Article 21. (Directive 2000/60/EC, Article 8).

According to all the above the strategy of the Hellenic State should follow specific directions, as below:

- Continual monitoring of quality and quantity of surface and groundwaters, at selected sites throughout Greece.
- Continual recording of the water needs by type of use and quantity, in every R.B.D..
- Integration of all involved authorities under the national and district water management units.

If this methodology is adopted, realistic and applicable policies will be decided, boosting development in every district, and moreover, these policies will be based on real facts, and not on theoretical models.

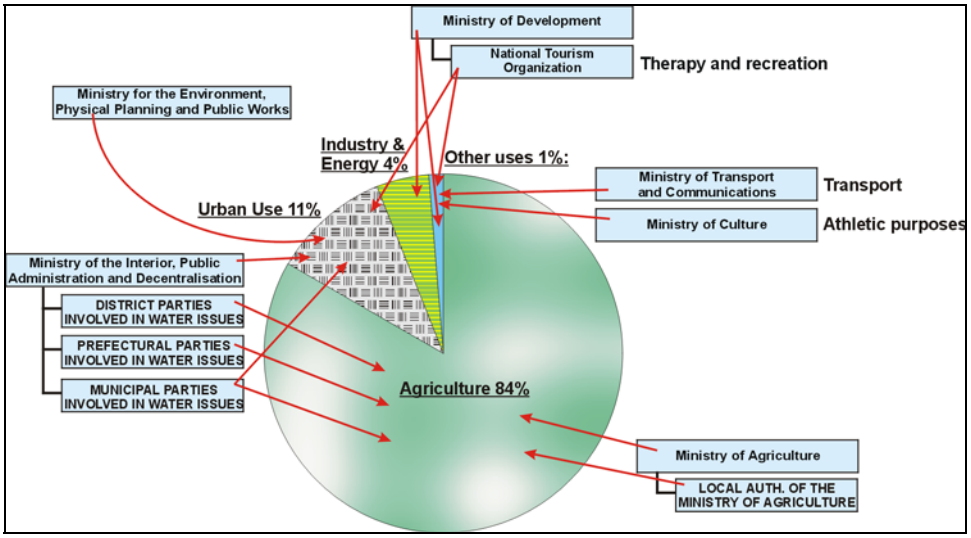

Figure 4: Present situation of water management and involved parties in Greece, by sectoral use of water (Data from European Environment Agency, 1999)

Until today, a large number of authorities and organizations with indefinite appositeness, are involved in water management in Greece. This results to a mazed management system, with none of the involved parties having neither a clear and overall picture of the situation of resources or needs, nor overall control. More specifically, according to data from the Ministry of Development, the following parties are involved in water management:

1. The Ministry of Agriculture, for agricultural use.

2. The Ministry of the Interior, Public Administration and Decentralisation, for water supply, except for the water supply of Athens and Salonica, that belongs to the Ministry for the Environment, Physical Planning and Public Works.
3. The Ministry for the Environment, Physical Planning and Public Works, for environmental protection uses.
4. The Ministry of Development, for industrial and energy production use, regardless of its responsibility for Natural Resources.
5. The Ministry of Transport and Communications, for the use of water in transport.
6. The Ministry of Culture, for water use for athletic purposes.
7. The National Tourism Organization, for therapeutic and recreation purposes
8. The Ministry of Development, for every other use.

In addition, a significant part of water management in Greece has to do with transboundary resources, that our country shares with neighbouring countries, such as Albania, FYROM, Bulgaria and Turkey. The European Union is particularly interested in this sector of water policies, and so a special reference is made in the Directive. On the other hand, the absence of a national organization of water resources management has lead to long inactivity towards the formulation of policies and agreements with neighbouring countries, during a period that water is the apple of discord, or even casus belli in other areas. This results to the absence of our country from international fora, where discussion on these matters takes place (i.e. the Internationally Shared/Transboundary Aquifer Resources Management project, supported by UNESCO, aiming at education, information and policy and decision making).

The Hellenic State, in harmonisation with the European policy, makes gradual adjustments in order to bring the desired effects, as described above. Till today, the management of R.B.D. is assigned to the relevant authorities of the Prefectures, which belong to the Ministry of the Interior. A trend is also shaping for the creation of a National Management Unit, either under the authority of the Ministry of Development, or the Ministry for the Environment, Physical Planning and Public Works. This unit, in addition to the existing management scheme, will only result to further complication and, as long as the limits of competence of each authority or organization are not completely discernible, the establishment of this unit doesn't appear to improve the situation (Fig.5).

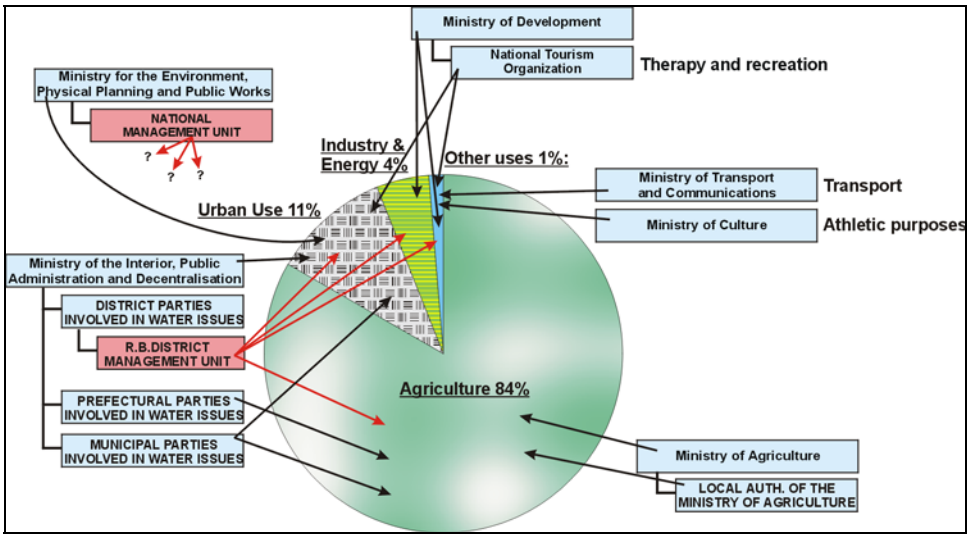

Figure 5: Present situation of water management and involved parties in Greece, by sectoral use of water, and actions planned by the authorities in accordance to the Directive (Data from European Environment Agency, 1999)

It is evident that the establishment of an independent authority of water recourses management is absolutely necessary. This authority should comprise one central and more peripheral units, one for

each R.B.D.. This National Management Unit should have a clear and complete picture and also the responsibility for the management of any water resource. In order for this to happen, it is imperative that all existing authorities involved in water management, are placed under this unified management system regarding both the updating and the responsibility, so there is a complete picture of water demand as well as the appropriate control of resources. The structure resulting from this modulation is depicted in Fig.6.

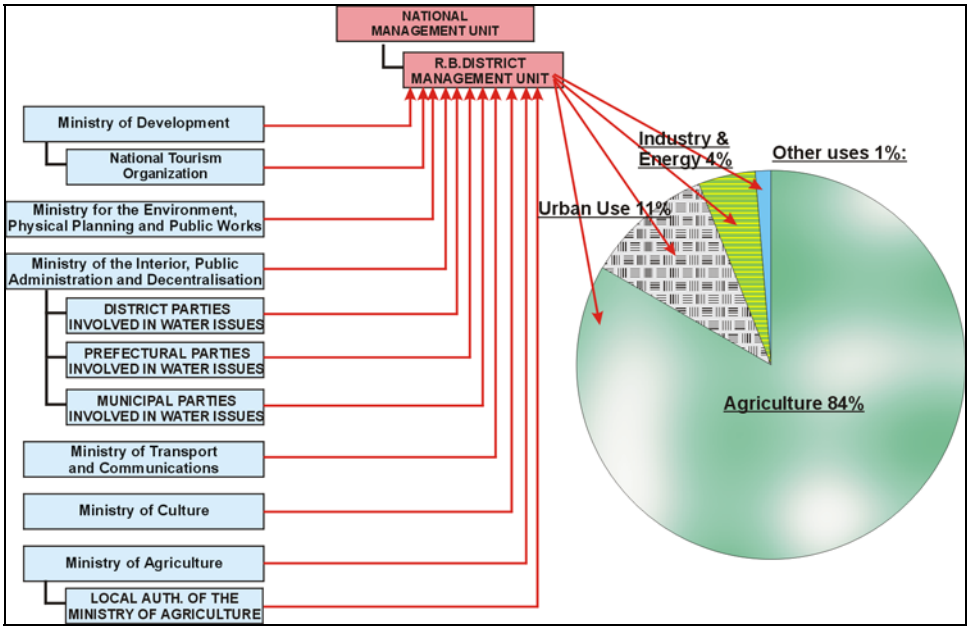

Figure 6: Proposed structure of an independent water management organisation, authorised for all actions concerning water in accordance to the Directive (Data from European Environment Agency, 1999)

4. THE PROPOSED MANAGEMENT STRUCTURE

The National Management Unit should operate on a double basis, i.e.:

- The flow of information. All information is collected at the lowest level, and is supplied to the central system above. Then, the total of information and the processed data are readily available for everyone, according to the level of access.
- The decision-making system and the licensing system. The distribution and scaling of authority in decision-making is important, since it facilitates the flexibility, the speed and the direct intervention to the system.

The hierarchy of each structural level should be completely discernible in relation to any other organization or office (public or private) involved, and its competency completely incontestable and legally secured.

The different existing local authorities (belonging mainly to the Ministry of Agriculture) will contribute to the implementation of the National Management Unit policies, in their respective structural level, and should adjust their function accordingly. For the needs of the National Management Unit the development of double software system is proposed, comprising the below-mentioned functions:

- A unified data base recording and reporting:
  - The quality, quantity and geographical distribution of water recourses potential, on three different levels (Municipal, Prefectural and National) and its dynamic

changes. The two lowest levels could be merged into the concept of the River Basin District Management Unit, as defined by Directive 2000/60/EC.

- The existing state of water consumption and demand from a qualitative, quantitative and geographical point of view, at the aforementioned levels, and their dynamic changes.

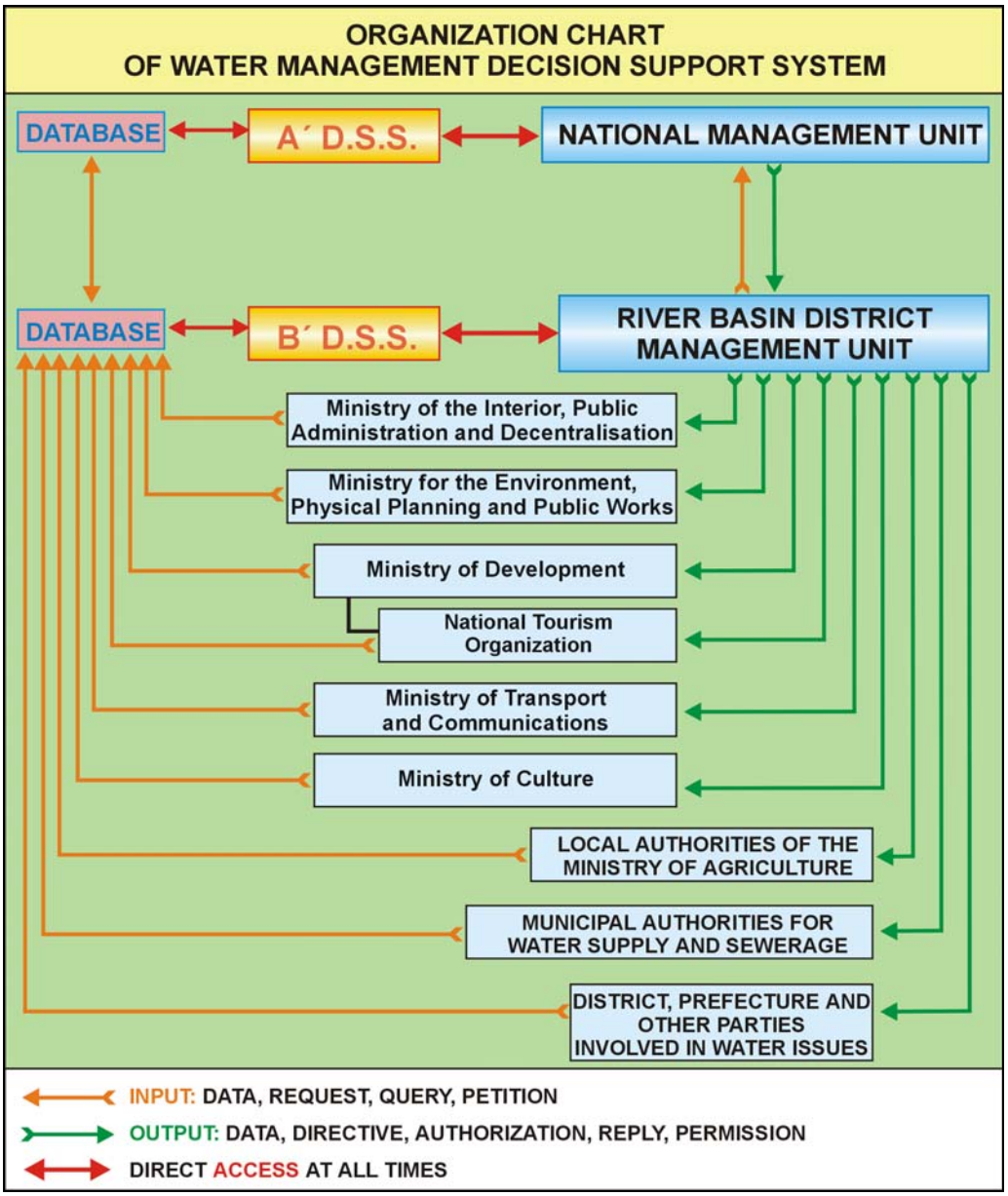

Figure 7: Structure and operation of the independent water management organization. Hierarchy of the different bodies is indicative, but the whole of data, information and management passes through the district water management units. The central unit interferes only in serious matters, and in the definition of the national strategy and the reviewing of the legislative framework

An integrated "cellular" Decision Support System (Figure 8) connected to and supported by the database, embodying the national and European legislation, in terms of sustainable development. This network will be assembled as below:

- A "first degree" cell (National Unit) (Fig.9),
- "Second degree" cells (River Basin District Units) (Fig.10),

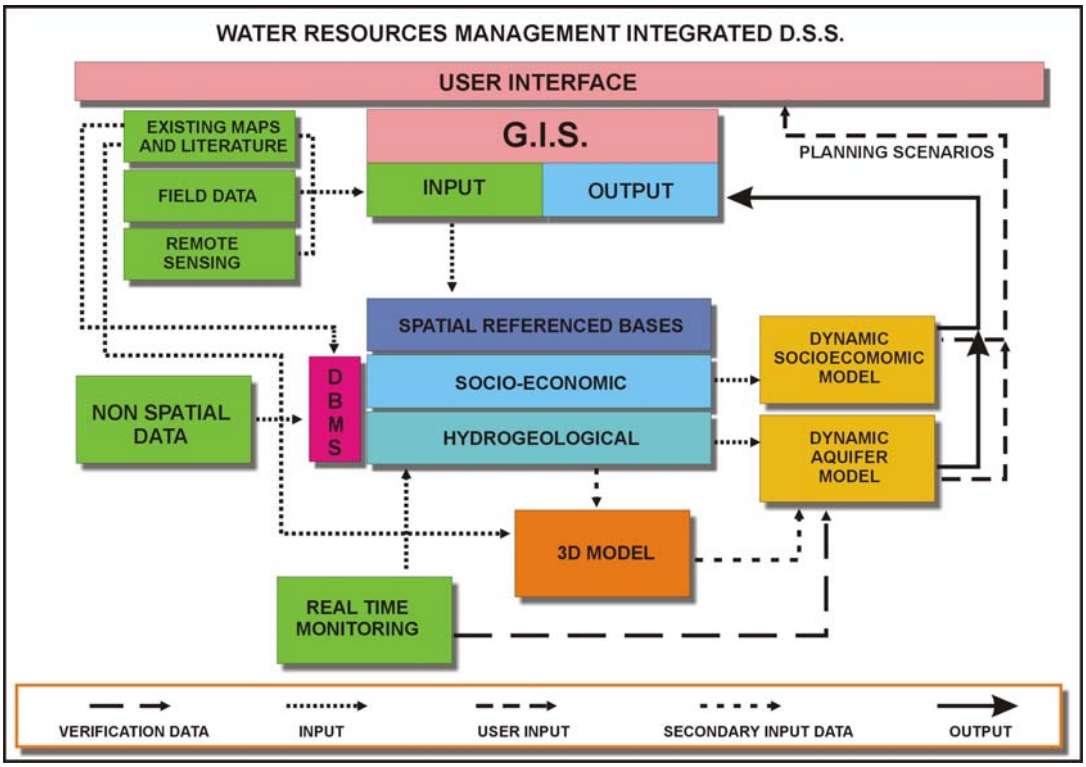

Figure 8: The elements of the proposed operational Integrated Decision Support System

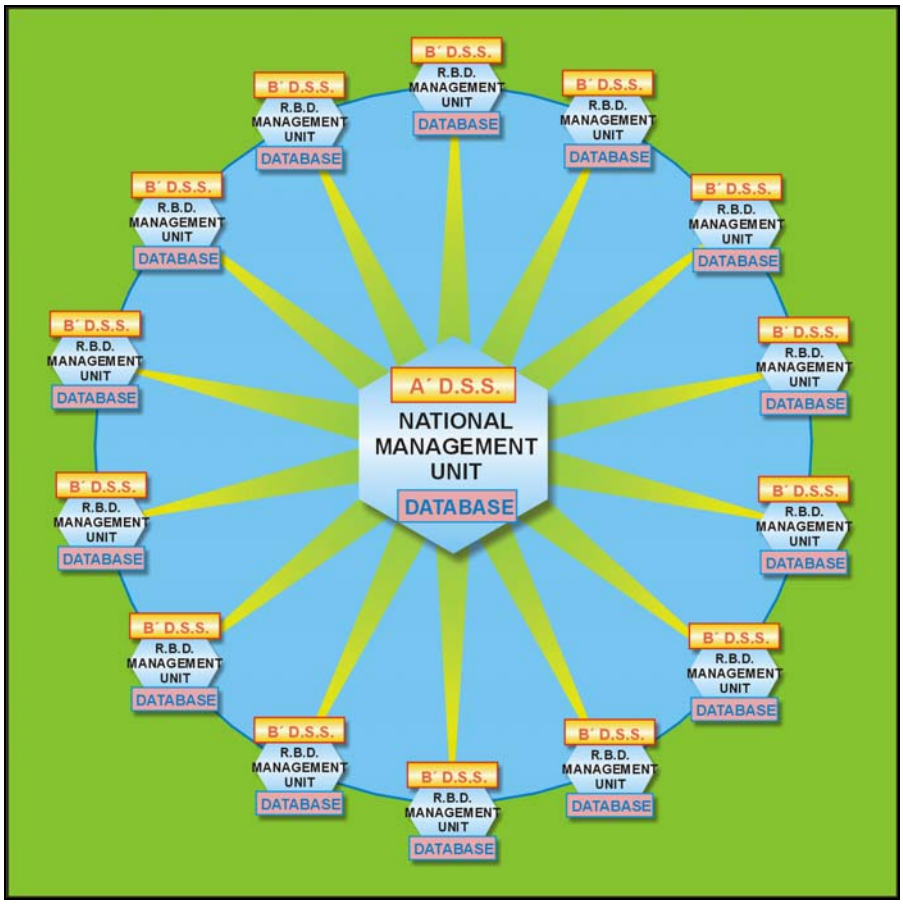

Figure 9:
The integrated platform of district and national water resources management.

5. KEY ACTIONS (WORK PACKAGES) NECESSARY FOR THE OPERATION OF THE INTEGRATED SYSTEM

A multi-parametric approach of water management demands the collection and analysis of a large volume of data, required for the efficient water resources management, in relation to the natural and human environment.

This procedure is divided into separate workpackages, as described on Table 1:

Table 1. Workpackages of the multi-parametric water resources management system.

1st Work Package	▪ Hydrogeological Research and Simulation ▪ Geometry of the Hydrogeological Structure of the Aquifer and 3D simulation ▪ Quality and Quantity attributes of the Aquifers ▪ Relation between surface and groundwater (quality - quantity)
2nd Work Package	▪ Monitoring – Quality and Quantity control of groundwater ▪ Monitoring of wells, drillholes, springs, etc.
3rd Work Package	▪ Monitoring – Quality and Quantity recording of surface waters and precipitation (hydrological cycle)
4th Work Package	▪ Selection of Methods of Enhancement of Water Resources and attainment of Good Surface and Groundwater Status and Good Ecological Status (Directive 2000/60/EC, Article 2). ▪ Selection of alternative methods of enhancement of water resources quantity and quality – Efficiency - Applicability ▪ Environmental Impact Assessment for every method ▪ Application of the selected methods ▪ Integration with the monitoring system
5th Work Package	▪ Socio-Economic Research and Simulation ▪ Data collection ▪ Data analysis – Evaluation of water management ▪ Alternative solution for management and development
6th Work Package	▪ Integrated Decision Support System (DSS) ▪ Software platform ▪ Integration of European and National legislation ▪ Application of Directions from workpackage 4. ▪ Continual updating of the system from workpackage 2, 3, 4 and 5.

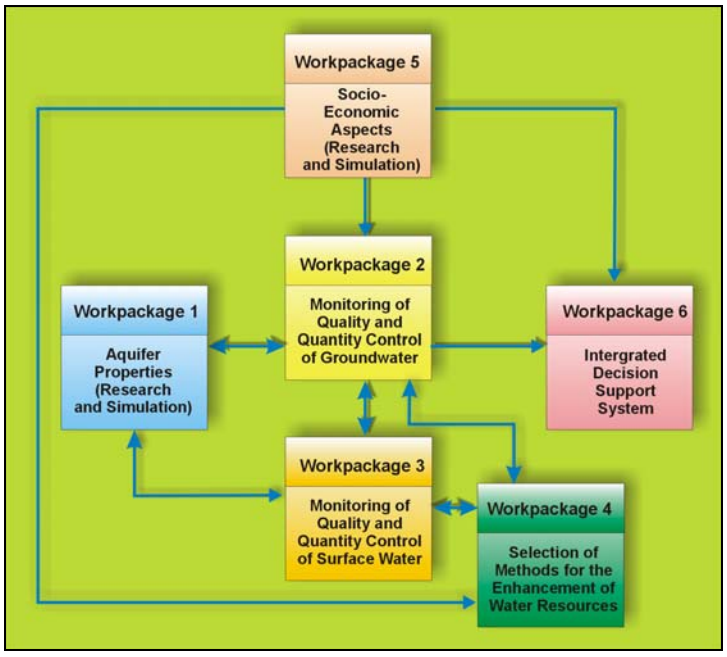

Figure 10:
The workpackages that build and refresh the knowledge status, and update the Decision Support System.

6. CONCLUSIONS

The timely and coordinated action of the Hellenic State is imperative, along the axes defined by the decisions of the European Parliament on a European level and on a uniform time plan. An advisory board covering a broad scientific spectrum, should determinate the planning of the management authorities, in cooperation with all involved ministries and authorities, and with support on matters of legislative documentation. All planning should be based on the time plan of the Directive 2000/60/EC, along with the estimation of the distribution of financial and human resources required for the implementation of the project.

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